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CIRCLE WEST

VEGETATION

MONITORING STUDY

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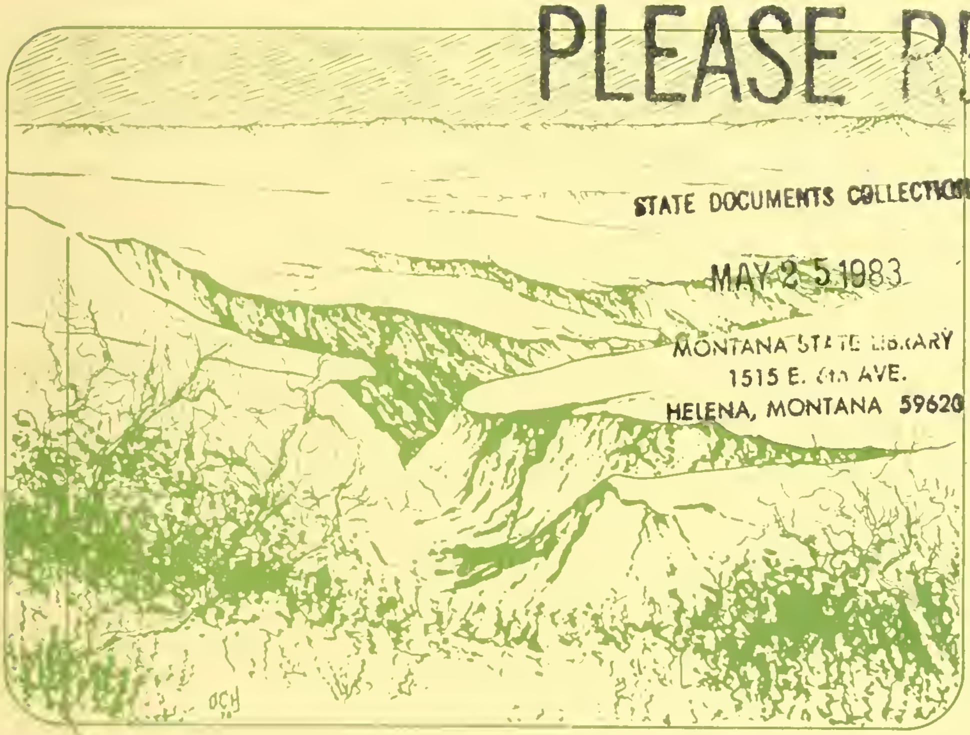

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FOURTH ANNUAL REPORT

Technical Report
No. 9

MONTANA DEPARTMENT OF NATURAL RESOURCES & CONSERVATION
ENERGY DIVISION
MARCH 1982
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Circle West Vegetation Monitoring Study

Fourth Annual Report

for the period

July 17 - August 10, 1981

Circle West Technical Report No. 9

R. Prodgers

under contract to the

Energy Division
Montana Department of Natural
Resources and Conservation
32 South Ewing
Helena, Montana 59620

March 1982

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INTRODUCTION

The Circle West Vegetation studies, established to describe existing vegetation and to monitor the long-term productivity and canopy-coverage of selected plant communities in McCone County, Montana, began in 1976 at the request of Dreyer Brothers, Inc.

The Circle West Vegetation Baseline Study (Prodgers 1978) identified community types for the study area through cluster analysis of 1976 vegetation data. Community types were described botanically and associated sites were characterized. Using this information, thirteen exclosures (figure 1) were chosen for long-term monitoring in order to provide a data base for assessment of strip mine reclamation success and possible air pollution effects. Productivity was measured at these exclosures from 1977 to 1981, and canopy-coverage was measured from 1978 to 1981 (Montana Department of Natural Resources and Conservation 1979a, 1979b, 1981.)

This fourth annual monitoring study is similar to those conducted in previous years. It compares 1981 data with that of the 1977 baseline study and the annual monitoring studies of subsequent years. In addition, new types of data have been added. Because of the dramatic effect of climate on plant community composition and productivity, and in accordance with DNRC's recommendations (DNRC 1981), climatic and soil moisture measurements have been added. Agricultural productivity and associated measurements also have been monitored and reported. Finally, at the request of the Department of State Lands, shrub density of the silver sagebrush exclosure (Arca/Agsm/Bogr community) has been measured and included in this report.

Due to an error in computer programming, productivity confidence intervals reported in the Third Annual Report (DNRC 1981) were miscalculated. Correct confidence limits are presented in this report.

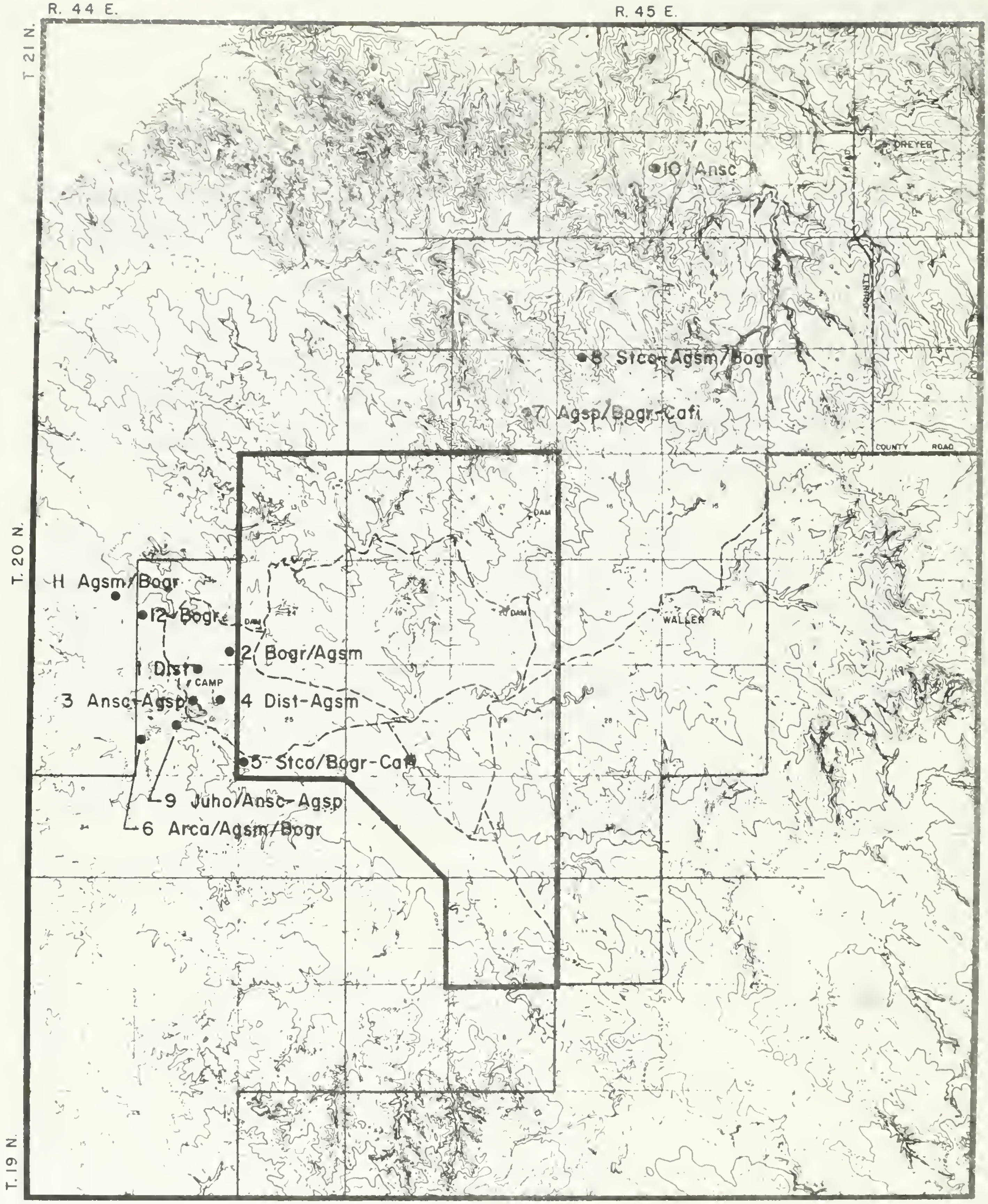

FIGURE I. LOCATION OF CIRCLE WEST VEGETATION EXCLOSURES

(NOTE: Exclosure 13, Bogr-Cafi/Stco, is located off the map in the southwest corner, Sec. 8, T. 20 N. R. 46 E.)

METHODS

Aerial Production

Twelve permanently fenced exclosures (figure 1) were sampled during the 1981 study. (Note: exclosure No. 9, Juho/Ansc-Agsp, shown on figure 1, was not sampled in 1981.) The 1981 productivity sampling procedures were the same as those used in 1977, 1978, 1979, and 1980. The number of samples to be taken per exclosure was calculated to obtain the desired levels of precision using the previous data. Sampling took place from July 17 through August 10, 1981.

After clipping, all exclosures except Ansc, Ansc-Agsp, and Agsp/Bogr-Cafi exclosures were opened for grazing to reduce litter accumulation from previous years. All exclosures were closed to grazing by autumn 1981.

Frequency and Canopy-Coverage

Within each exclosure, twenty permanently located 20 cm x 50 cm plots were sampled for frequency and plant canopy-coverage using a modification of the technique described by Daubenmire (1959). Unlike Daubenmire's technique, coverage classes were not used, but plant canopy-coverage for each species was estimated as accurately as possible. The same series of plots were sampled in 1981 as in previous years. These plots have never been clipped. Color transparencies of each plot were taken at the time of sampling.

Species Density

Species density, the simplest measure of diversity, was determined for each community based upon canopy-coverage data. In each exclosure, the average number of species per plot (species density) and the number of species per set of twenty plots were calculated.

Silver Sagebrush Density

Prior to clipping of the Arca/Agsm/Bogr exclosure, density of silver sagebrush was measured in 45 0.5m^2 plots randomly selected for clipping. Shrubs were assigned to one of three size categories:

Shrub Category	Definition
Small	Under 12 inches high, small crown, one or a few stems.
Medium	12 to 24 inches high (usually), well developed crown, one to several stems.
Large	Over 24 inches high, large crown, several stems.

Climate and Readily Available Soil Moisture

Since climatic variations are thought to be responsible for much of the natural variation exhibited by the plant communities studied, the most important climatic factors were measured this year and will continue to be measured in subsequent studies if possible. These factors are: precipitation, temperature, and available soil moisture at various depths in the rooting zone.

Precipitation was measured using a standard rain and snow gauge located at the Dreyer Ranch headquarters (NW 1/4, Sec. 36, T.21 N, R.45 E). This gauge, shielded by a wind screen, is located in a field over 50 yards from any objects that could affect measurements. Another rain gauge (wedge type) is located along Nelson Creek (north central portion of Sec. 25, T.20 N, R.44 E). A temperature-recording device is located on the north side of the Dreyer ranch house.

Readily available soil moisture, defined as the difference between soil moisture (as sampled) and the permanent wilting percentage (determined for the soil at each sample site), has been determined for the following communities: Arca/Agsm/Bogr, Agsp/Bogr-Cafi, Ansc, Bogr-Cafi/Stco, Stco-Agsm/Bogm, and Bogr/Agsm. Readily available soil moisture was also determined for a wheat field in Sec. 4, T.19 N, R.45 E. In both cases, the methods of Daubenmire (1974) were used. Samples were taken in June, July, August, and September. Since June samples were thought to have dried in transport, data for June have been deleted.

Vascular Plant Collections

Vascular plant species not previously observed in the study area were collected and identified. Plant specimens were collected in May, August, and September 1981. A special attempt was made to locate *Rorippa calycina* (Engelm.) Rydb. Var. *calycina*.

RESULTS AND ANALYSIS

Aerial Production

Tables 1 through 12 and figures 2 through 5 summarize productivity and litter-accumulation data collected during the 1977-1981 study period. Means are expressed in kilograms per hectare with 90% confidence limits. (For pounds per acre, multiply kilogram per hectare values by 0.892.) When data from both halves of each exclosure were compared for internal homogeneity, only the Ansc community was not homogeneous at the .05 probability level.

Productivity in 1981 was higher than in 1980, a drought year, and, in most cases, was similar to productivity in 1979. Both 1979 and 1981 are characterized by below-average precipitation during the growing season. However, the dry summer of 1979 followed a wet year and winter of heavy snowfall, whereas the summer of 1981 followed a drought year and dry winter.

Communities exhibiting production similar to 1979 levels are Stco/Bogr-Cafi, Bogr-Cafi/Stco, Stco-Agsm/Bogr, Bogr/Agsm, Agsm/Bogr, Ansc-Agsp, and Agsp/Bogr-Cafi. The Dist community continued to slowly but steadily increase in productivity, probably as a result of protection from grazing and the presence of subsurface water, although water availability is modified by soil salts. Production in the two warm-season communities, Bogr and Ansc, was only two-thirds of that measured in 1979. Production in the Arca/Agsm/Bogr community did not regain the level measured in 1979 when unusually high productivity was thought to result from snow accumulation in this coulee site. Productivity of the Dist-Agsm community was higher than in 1979, possibly as a result of grazing in late 1980, but the difference was not significant ($p > .10$).

Frequency and Canopy-Coverage

Table 13 presents the canopy-coverage data for 1981. Compared to 1980 data, the most significant change is a substantial reduction in canopy-coverage of *Bouteloua gracilis* in six communities (Arca/Agsm/Bogr, Stco/Bogr-Cafi, Bogr-Cafi/Stco, Bogr/Agsm, Agsp/Bogr-Cafi, and Stco-Agsm/Bogr). Canopy-coverage of *B. gracilis* in these communities in 1981 averages 14.0% compared to 23.6% in 1980, a 59% decrease.

Other changes from 1980 include an increase in coverage of *Stipa comata* in the Bogr-Cafi/Stco community, an increase of *Carex filifolia* and decrease of *Muhlenbergia cuspidata* in the Ansc-Agsp community, an increase of *Agropyron smithii* in the Bogr-Agsm community, and a decrease of *Distichlis stricta* in the Dist-Agsm community. (See DNRC 1981 for 1980 data.)

Table 1. *Distichlis stricta* Community Productivity (kg/ha)

	Dist	Litter	Σ Productivity
1977	970± 89	430± 60	970± 89
1978	1055± 110	416± 79	1075± 105
1979	1226± 122	348± 128	1230± 119
1980	1477± 145	1147± 411	1526± 129
1981	1674± 269	1108± 289	1732± 313

Table 2. *Distichlis stricta* - *Agropyron smithii* Community Productivity (kg/ha)

	Dist	Agsm	Hemi	Litter	Σ Productivity
1977	676 ± 130	72 ± 20	51± 18	1071± 184	813± 114
1978	1393 ± 165	418 ± 99	167± 51	521± 72	2071± 214
1979	856 ± 156	252 ± 68	164± 35	1432± 206	1248± 189
1980	585 ± 102	108 ± 27	92± 33	2434± 455	778± 87
1981	938 ± 114	343 ± 65	167± 72*	2257± 408	1481± 114

* Including *Bouteloua gracilis*, *Stipa comata*, *Carex filifolia*, *Artemisia frigida*, and *Koeleria pyramidata* (Lam.) Beauv. A patch of *Spartina gracilis* is expanding outside the sample area of this exclosure.

Table 3. *Bouteloua gracilis* Community Productivity (kg/ha)

	Bogr	Litter	Σ Productivity
1977	170± 14	38± 38	198± 24
1978	513± 160	375± 61	778± 227
1979	606± 99	458± 178	632± 102
1980	199± 20	790± 415	199± 20
1981	319± 25	166± 110	434± 45*

* Including 65 kg/ha of *Festuca octoflora*.

Table 4. *Agropyron smithii*/*Bouteloua gracilis* Community Productivity (kg/ha)

	Agsm	Bogr	Litter	Σ Productivity
1977	144± 45	44± 13	578± 166	202± 47
1978	1062± 132	414± 75	363± 65	1672± 142
1979	464± 71	130± 24	994± 178	674± 70
1980	7.2± 3.5	193± 84	1187± 152	217± 84
1981	238± 48	280± 36	841± 109	759± 70*

* Including 201 kg/ha of therophyte production, mostly *Festuca octoflora*.

Table 5. *Bouteloua gracilis*/*Agropyron smithii* Community Productivity (kg/ha)

	Bogr	Agsm	Litter	Σ Productivity
1977	12 ± 3.6	3.6 ± 2.2	38 ± 10	16 ± 5.9
1978	203 ± 52	1610 ± 228	280 ± 47	1955 ± 251
1979	134 ± 24	528 ± 62	1460 ± 195	674 ± 65
1980	258 ± 61	72 ± 35	1758 ± 316	331 ± 48
1981	244 ± 36	522 ± 64	1356 ± 264	768 ± 54

Table 6. *Stipa comata*/*Bouteloua gracilis* - *Carex filifolia* Community Productivity (kg/ha)

	Stco	Bogr	Litter	Σ Productivity
1977	189 ± 23	22 ± 6	162 ± 29	218 ± 25
1978	856 ± 102	54 ± 21	120 ± 36	1141 ± 96
1979	312 ± 66	54 ± 10	536 ± 123	798 ± 62
1980	383 ± 109	86 ± 32	1020 ± 203	633 ± 79
1981	456 ± 72	30 ± 9	255 ± 90	702 ± 76*

* Including *Carex filifolia*, *Agropyron smithii*, *Koeleria pyramidata* (Lam.) Beauv. and *Astragalus pectinatus*.

Table 7. Bouteloua gracilis - Carex filifolia/Stipa comata Community Productivity (kg/ha)

	Bogr	Cafi	Stco	Litter	Σ Productivity
1977	131 ± 28	95 ± 15	138 ± 26	247 ± 48	406 ± 39
1978	253 ± 49	183 ± 48	662 ± 118	267 ± 62	1290 ± 176
1979	228 ± 82	170 ± 76	334 ± 96	558 ± 146	840 ± 104
1980	248 ± 40	86 ± 49	136 ± 62	763 ± 149	505 ± 96
1981	140 ± 20	125 ± 19	460 ± 70	331 ± 65	802 ± 57

Table 8. Stipa comata - Agropyron smithii/Bouteloua gracilis Community Productivity (kg/ha)

	Stco	Agsm	Bogr	Hemi	Litter	Σ Productivity
1977	97 ± 15	68 ± 23	70 ± 19	56 ± 14	417 ± 70	334 ± 38
1978	354 ± 95	421 ± 99	93 ± 40	342 ± 93	356 ± 90	1420 ± 119
1979	194 ± 66	370 ± 122	140 ± 34	118 ± 38	914 ± 297	886 ± 120
1980	84 ± 24	103 ± 30	90 ± 40	52 ± 28	1231 ± 126	344 ± 38
1981	162 ± 43	447 ± 47	115 ± 23	104 ± 28*	894 ± 110	852 ± 35

* Mostly Carex filifolia with lesser amount of Poa secunda.

Table 9. Andropogon scoparius Community Productivity (kg/ha)

	Ansc	Hemi	Litter	Σ Productivity
1977	800 ± 160	68 ± 22	1084 ± 198	840 ± 146
1978	698 ± 101	194 ± 61	660 ± 127	1049 ± 114
1979	954 ± 217	120 ± 27	734 ± 222	1056 ± 279
1980	161 ± 26	132 ± 40	1247 ± 343	339 ± 37
1981	415 ± 76	253 ± 41*	525 ± 114	738 ± 68

* Mostly Muhlenbergia cuspidata, Koeleria pyramidata (Lam.) Beauv., and Stipa comata.

Table 10. *Andropogon scoparius* - *Agropyron spicatum* Community Productivity (kg/ha)

	Ansc	Agsp	Hemi	Litter	Σ Productivity
1977	102 ± 64	182 ± 38	208± 36	946 ± 182	560 ± 73
1978	128 ± 91	315 ± 95	513± 93	438 ± 138	1152 ± 145
1979	104 ± 92	268 ± 79	394± 92	774 ± 174	902 ± 128
1980	26 ± 25	132 ± 43	261± 91	1051 ± 229	465 ± 68
1981	75 ± 42	546 ± 94	323± 71*	761 ± 159	1004 ± 66**

* Mostly *Carex filifolia*, *Muhlenbergia cuspidata*, *Aristida longiseta*, *Stipa comata*, and *Ratibida columnifera*.

** Including 57 kg/ha of the chamaephytes *Guitierrezia sarothrae* and *Artemisia frigida*.

Table 11. *Agropyron spicatum*/*Bouteloua gracilis* - *Carex filifolia* Community Productivity (kg/ha)

	Agsp	Bogr	Cafi	Hemi	Cham*	Litter	Σ Productivity
1977	116± 22	39± 15	36± 10	44± 14	142± 66	727± 158	372± 42
1978	517± 126	58± 34	78± 21	365± 75	183± 64	306± 72	1284± 90
1979	596± 92	48± 18	52± 11	86± 35	96± 31	520± 72	866± 123
1980	143± 49	74± 46	30± 8	51± 30	134± 76	1021± 302	441± 63
1981	483± 68	32± 9	68± 12	91± 33*	138± 37**	756± 116	835± 56

* Mostly *Stipa comata* with lesser *Koeleria pyramidata* (Lam.) Beauv.

** Mostly *Eurotia lanata* and *Gutierrezia sarothrae* with lesser *Phlox hoodii* and *Artemisia frigida*.

Table 12. *Artemisia cana*/*Agropyron smithii*/*Bouteloua gracilis* Community Productivity (kg/ha)

	Arca	Agsm	Bogr	Hemi	Litter	Σ Productivity
1977	398± 153	115± 28	134± 35	80± 31	753± 246	800± 162
1978	602± 139	666± 157	262± 63	258± 79	633± 178	2024± 168
1979	698± 327	656± 114	418± 100	138	1752± 591	1970± 295
1980	278± 112	132± 43	321± 93	52	6929± 3317	763± 143
1981	430± 127	485± 63	204± 41	70*	2046± 320	1237± 111

* Mostly *Stipa comata*, *Stipa viridula*, and *Gaura coccinea*.

TABLE 13. Botanical Composition of Communities Based Upon Average Canopy-Coverage and (Frequency) N = 20

	Arca/ Agsm/ Bogr	Stco/ Bogr- Cafi	Bogr- Cafi/ Stco	Ansc- Agsp	Bogr/ Agsm	Agsm/ Bogr	Agsp/ Bogr- Cafi	Dist- Agsm	Bogr	Stco- Agsm/ Bogr	Dist	Ansc
Achillea millefolium								1.1 (40)				
Agropyron smithii	13.9(100)[1]	5.2(100)	0.2(15)		16.6(100)	11.7(100)		7.9(100)	0.8(10)	12.6(100)		
Agropryon spicatum				15.0(90)			27.8(100)					3.0 (30)
Allium textile				0.1(5)			+ (5)[2]					
Andropogon scoparius				6.1(70)								38.6 (95)
Antennaria parvifolia												0.5 (10)
Arabis sp.												0.1 (5)
Aristida longiseta				12.9(45)								
Artemisia campestris												0.4 (10)
Artemisia cana	46.8(85)											
Artemisia frigida	1.2(25)			3.0(45)				2.9(15)		1.1(20)		0.5 (15)
Aster falcatus				0.8(15)								0.4 (10)
Astragalus spatulatus				0.1(5)								
Astragalus sp.												0.1 (5)
Bouteloua gracilis	15.7(75)	8.3(100)	13.7(100)		25.7(100)	28.0(100)	9.2(95)	2.6(40)	61.0(100)	11.4(100)		0.2 (10)
Calamovilfa longifolia	0.1(5)			0.1(5)								0.3 (5)
Campanula rotundifolia				1.3(10)								
Carex filifolia	0.8(15)		11.7(100)	16.6(70)			7.3(95)	1.2(10)		9.5(85)		3.3 (30)
Carex pensylvanica												0.9 (10)
Carex stenophylla		0.2 (20)			2.8(55)	11.4(100)				1.4(35)		
Chenopodium leptophyllum								+ (5)				
Chrysopsis villosa				1.8(5)								
Conyza canadensis								0.1 (5)				
Coryphantha vivipara						0.1(10)						
Distichlis stricta								27.8(100)			43.3(100)	
Echinaceae pallida				+ (5)								2.7 (65)
Erigeron sp.							0.1 (5)					
Eurotia lanta	0.7(5)						4.8(40)			0.2(5)		
Festuca octoflora					0.1(10)	2.3(65)			3.0(90)			
Gaura coccinea	0.2(10)		2.4(45)									
Gutierrezia sarothrae				1.5(15)			4.8(50)					0.2 (5)

TABLE 13. Botanical Composition of Communities Based Upon Average Canopy-Coverage and (Frequency) N = 20 (Continued)

	Arca/ Agsm/ Bogr	Stco/ Bogr- Cafi	Bogr- Cafi/ Stco	Ansc- Agsp	Bogr/ Agsm	Agsm/ Bogr	Agsp/ Bogr- Cafi	Dist- Agsm	Bogr	Stco- Agsm/ Bogr	Dist	Ansc
Hedeoma hispida					0.1(15)	+ (5)	+ (5)	0.1 (15)	0.1(10)	+ (5)		
Koeleria cristata	0.4(10)			3.0(70)			0.9(20)	0.4(10)		1.9(30)		4.8(80)
Lappula redowskii												+ (5)
Lepidium densiflorum			0.2(5)							0.1(20)		
Lesquerella alpina				0.4(20)								0.1(5)
Liatris punctata				0.1(5)								
Linum rigidum	0.1(10)		0.1(5)				0.1(15)			0.5(35)		
Lygodesmia juncea		5.3(30)	0.5(20)							1.2(10)		
Microseris cuspidata												0.2(10)
Muhlenbergia cuspidata				3.0(40)								6.4(60)
Opuntia fragilis					0.1(5)			0.1(5)				
Opuntia polyacantha					0.4(5)							
Penstemon sp.												0.1(5)
Petalostemon sp.				1.0(20)								1.5(15)
Phlox hoodii			2.0(40)				3.9(65)	0.5(15)		1.3(20)		0.8(30)
Plantago patagonica	0.1(10)		0.1(10)					0.1(15)		0.2(35)		+ (5)
Poa sandbergii					0.3(5)				1.9(65)	1.7(40)		
Polygala alba				0.8(15)								
Ratibida columnifera				0.2(10)								
Rosa arkansana												0.5(15)
Sphaeralcea coccinea	0.1(5)	0.1(5)					0.3(15)					
Solidago missouriensis												0.6(15)
Solidago nana												2.6(20)
Stipa comata	1.7(15)	53.6(100)	37.8(100)	7.5(70)		1.8(15)	11.3(70)	5.3(55)		16.1(95)		2.0(35)
Stipa viridula	2.5(20)			0.1(5)								
Suaeda depressa											1.7(15)	
Taraxacum officinale								0.3(25)				+ (5)
Mosses and Lichens	2.5(95)	2.5(100)	7.1(100)	4.4(100)	3.3(100)	17.5(100)	2.4(100)	5.0(100)	0.8(100)	17.1(100)		2.0(35)
Bare Ground	2.0(80)	14.6(100)	18.3(100)	17.9(100)	14.8(100)	8.5(100)	15.0(100)	3.2(100)	4.4(100)	2.9(100)	25.3(100)	37.0(100)
Litter	89.6(100)	44.2(100)	37.5(100)	45.8(100)	64.8(100)	59.5(100)	55.3(100)	75.2(100)	64.5(100)	60.5(100)	35.8(100)	46.2(100)

1) Canopy-Coverage (frequency).
2) Present, less than 0.1% average canopy-coverage.

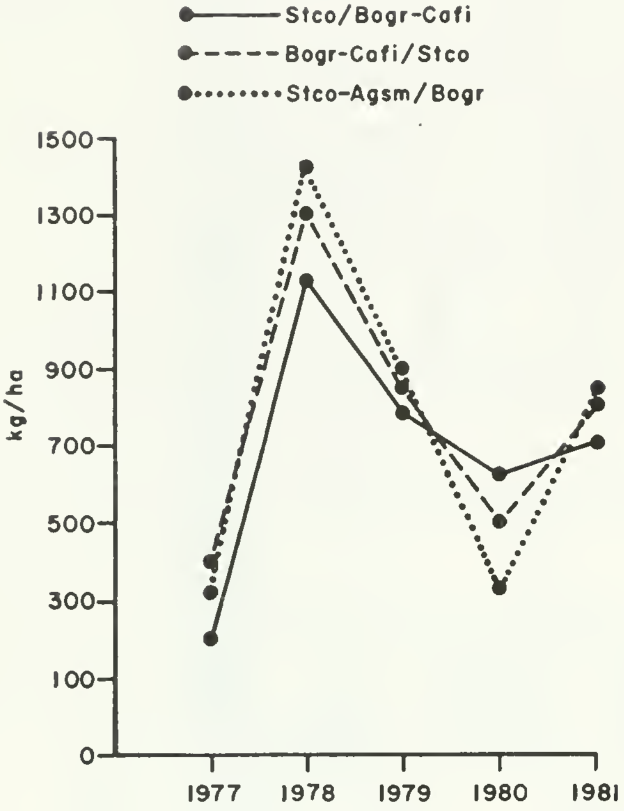

Figure 2. Net aerial production in Stco/Bogr-Cafi, Bogr-Cafi/Stco, and Stco-Agsm/Bogr communities, 1977-1981.

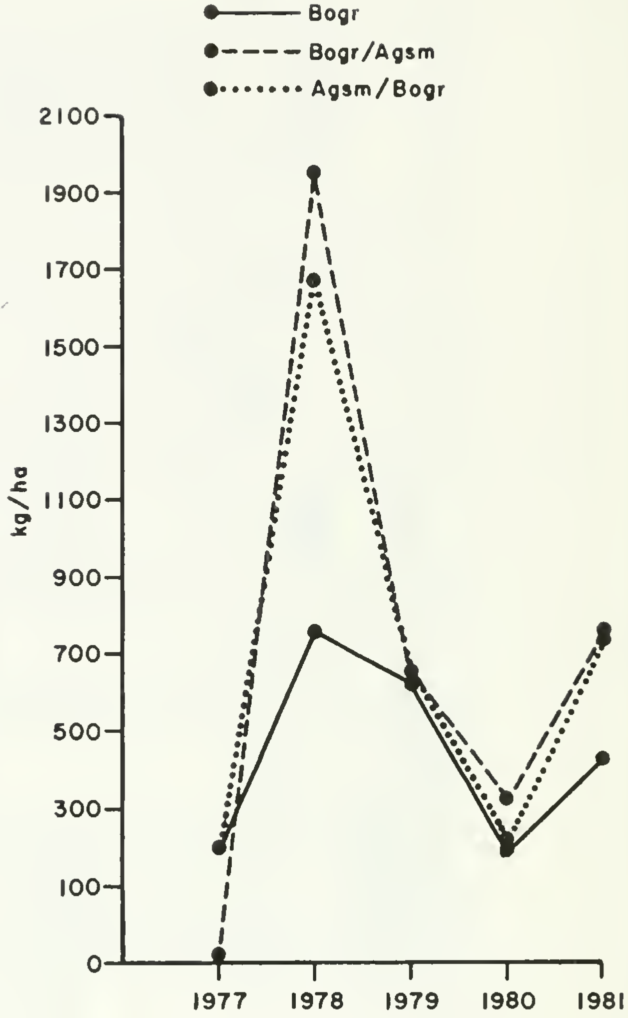

Figure 3. Net aerial production in Bogr, Bogr/Agsm, and Agsm/Bogr communities, 1977-1981.

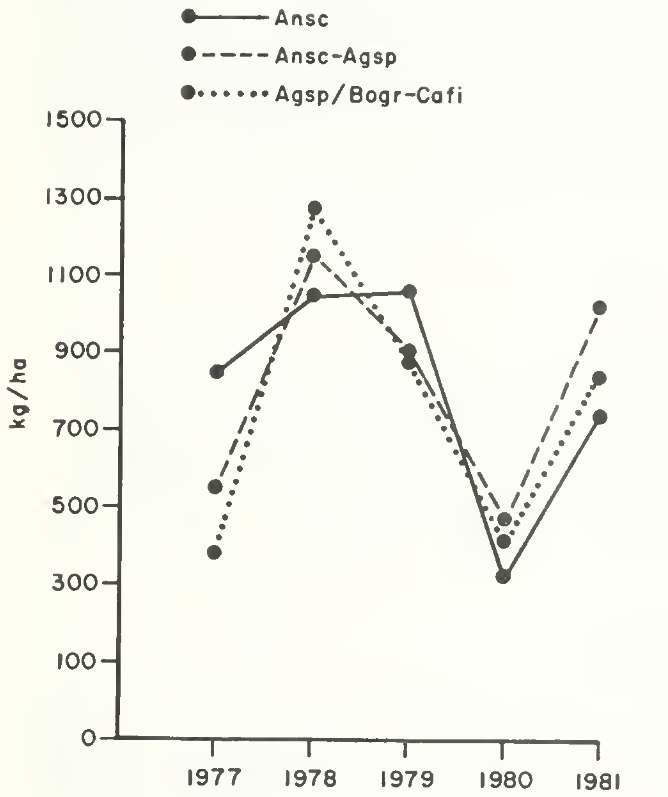

Figure 4. Net aerial production in Ansc, Ansc-Agsp, and Agsp/Bogr-Cafi communities, 1977-1981.

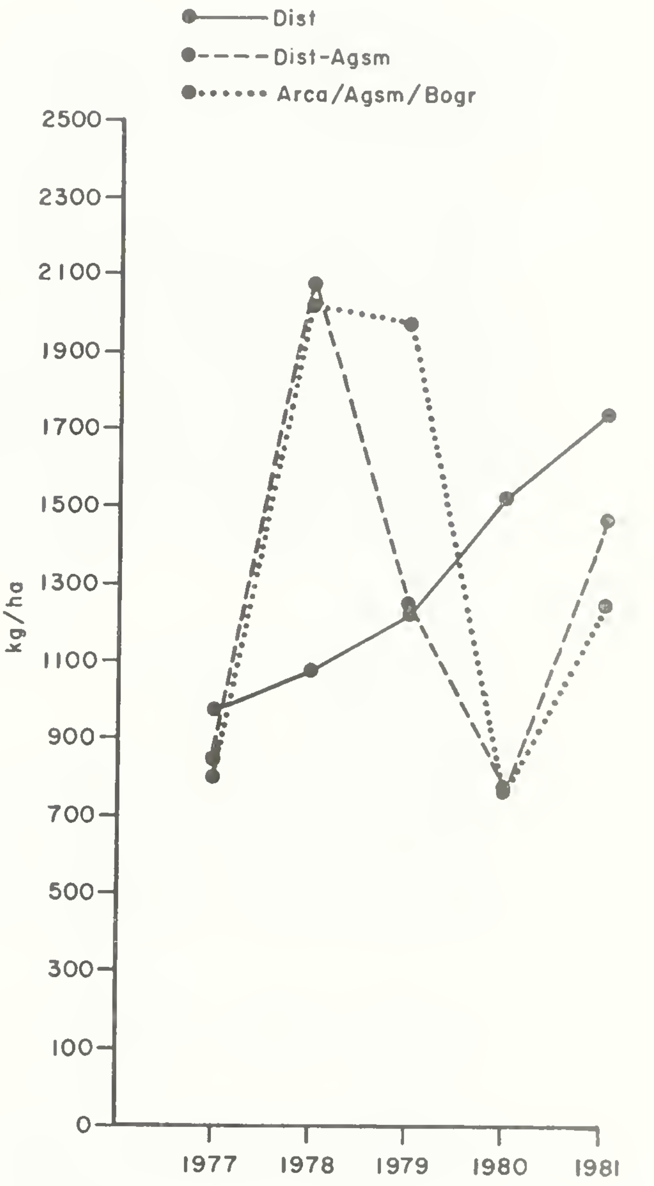

Figure 5. Net aerial production in Dist, Dist-Agsm, and Arca/Agsm/Bogr communities, 1977-1981.

Species Density

Table 14 shows species density for 1981. In general, species density increased substantially from 1980 levels. (See DNRC 1981.) The extent of increase, however, is variable. The Ansc community shows the greatest change in species density. Average species per $0.1m^2$ plot jumped from three to five during the 1978-1980 period and to 6.2 in 1981, while the number of species per 20 plots jumped from 20 and 22 during the 1978-1980 period to 29 in 1981.

These changes in the Ansc community seem to be a result of the 1980 drought, from which it has not recovered. The increase in species density may be a result of *Andropogon scoparius* mortality and a consequent increase in sites available for colonization by other species. Canopy-coverage of *A. scoparius* decreased from 55.5% in 1978 and 60.2% in 1979 to 41.4% in 1980 and 38.6% in 1981. Production levels of *A. scoparius* in the Ansc community decreased from an average 85% of total production during the 1978 and 1979 period to 52% of total production during the 1980 and 1981 period. This community was the only one not internally homogeneous in 1981. (It also was determined to be non-homogeneous in 1977 and 1979.) *Agropyron spicatum*, not an aggressive species in the study area, is now present throughout the Ansc community in small quantities.

Silver Sagebrush Density

Total silver sagebrush density as determined by 45 $0.5m^2$ samples is 7.78 individuals per square meter with a frequency of 87%. Small individuals exhibited a density of $5.87/m^2$ and a frequency of 80%. Medium-size individuals exhibited a density of $1.55/m^2$ and a frequency of 40%. Large individuals had a density of $0.35/m^2$ and a frequency of 13%.

Climate and Readily Available Soil Moisture

Precipitation data for the recording period are presented in table 15. Readily available soil moisture is shown in table 16. Accurate temperature data were not collected until August due to difficulties with equipment operation. These data are therefore not presented, although thermographs are on file at DNRC.

May-June precipitation was 3.2 inches. Only 1.1 inches of this total came from rains depositing 0.5 inches of precipitation or more in a 24-hour period. By July, readily available soil moisture was 7% or less in the rooting zones of all communities with the exception of the 3-inch depth of the Arca/Agsm/Bogr community. The upper soil level of some communities showed some improvement in August, but was once again near exhaustion by September. Readily available soil moisture in the Stco-Agsm/Bogr community was nearly nonexistent throughout the sample period except at the 30-inch depth.

Vascular Plant Collections

Appendices A and B list all species of vascular plants which have been observed in the study area through 1981. A single specimen of *Rorippa calycina* var. *calycina* (now housed at the University of Montana herbarium) was collected in August 1980 by Rich Prodgers near a large stockpond approximately one mile southwest of the Dreyer Brothers' ranchhouse. This area and similar habitat was searched for *R. calycina* by R. Prodgers and D. Ramsden, DNRC contractors, and B. Lichtvar, botanist for the Wyoming Heritage Program, during the summer of 1981. No further specimens, however, were found. The occurrence of this species is rare. It is known from limited sites: three in Montana, one in the Northwest Territories, Canada, and several in Wyoming. A healthy population currently exists at Seminoe Reservoir, Wyoming, which appears to be the distributional center and primary seed source for the species (B. Lichtvar, personal communication). *R. calycina* is apparently a fugitive species, transported by waterfowl but seldom establishing a viable population. The specimen obtained in the study area may represent an individual occurrence of *R. calycina* rather than an established population, since a careful search failed to provide additional specimens.

TABLE 14. Species Density

Community	Average Species per 0.1m^2 plot	Species per 20 plots
Dist	1.2	2
Bogr	2.7	5
Bogr/Agsm	3.0	8
Stco/Bogr-Cafi	3.6	6
Arca/Agsm/Bogr	3.9	14
Agsm/Bogr	4.0	7
Bogr-Cafi/Stco	4.4	10
Dist-Agsm	4.9	17
Ansc	6.2	29
Agsp/Bogr-Cafi	6.4	14
Stco-Agsm/Bogr	6.5	15
Ansc-Agsp	6.6	22

TABLE 15. Precipitation at Dreyer Ranch (May to November 1981)

Date	Precipitation in Inches
5/7	0.5
5/10	0.3
5/16	0.1
5/22	0.1
5/27	0.2
5/30	0.5 (Total for May: 1.7)
6/12	0.3
6/13	0.6
6/14	0.2
6/15	0.4 (Total for June: 1.5)
7/11	0.5
7/17	0.3
7/18	0.4 (Total for July: 1.2)
8/4	1.2
8/15	0.7 (Total for August: 1.9)
9/29	0.4 (Total for September: 0.4)
10/12-10/14	1.4 (Total for October: 1.4)
11/18	0.3 (Total for November: 0.3)

TABLE 16. Readily Available Soil Moisture for Selected Communities

Community	Depth in inches	Texture			Percent Moisture @ 15 bars[b]	Percent Readily Available Soil Moisture on dry weight basis		
		% Sand	% Silt	% Clay		7/5/81	8/15/81	9/5/81
Bogr/Agsm	3	32	42	26	10.71	2.54	12.54	7.62
	10	20	40	40	10.42	4.14	14.53	8.32
	24	40	32	28	7.21	3.42	5.4	11.84
Bogr-Cafi/ Stco	3	76	12	12	5.78	4.82	3.94	-3.40
	15	80	8	12	3.99	5.09	2.06	0.54
	30	68	16	16	5.05	3.98	0.98	-0.36
Stco-Agsm/ Bogr	3	34	38	28	9.49	2.76	1.27	-1.75
	10	22	42	36	12.02	0.73	-1.97	-2.56
	18	20	44	36	10.47	-0.13[c]	0.87	-1.90
	30	48	48	4	2.40	6.81	5.89	5.29
Arca/Agsm/ Bogr	3	36	40	24	5.85	12.59	11.25	3.34
	12	32	46	22	5.28	3.02	6.73	5.51
	20	28	50	22	6.25	3.88	3.56	0.87
	30	30	48	22	5.96	1.97	2.93	0.84
Ansc	3	60	32	8	7.62	0.57	1.55	-0.61
	12	72	12	16	6.43	3.53	13.18	2.16
	22	72	16	12	5.84	3.35	8.32	1.40
Agsp/Bogr-Cafi	3	40	40	20	5.34	6.36	8.98	-0.79
	12	32	40	28	7.59	3.59	1.52	2.78
	22	22	38	40	6.54	3.16	2.65	5.43
	30	30	32	38	7.42	1.85	2.01	1.17
Wheat Field[a]	3	68	22	10	4.54	-0.01	12.31	-1.97
	14	42	42	16	6.79	0.27	12.34	-3.14
	18	40	38	22	7.24	-0.18	16.32	-3.44

(a) This 215.1 acre field was planted to Nevanna spring wheat on 4/18/81. Seed was applied at a rate of 60 lbs/acre with a disc drill set for 7-inch spacing. Fertilizer consisting of 46% total nitrogen and 18% available phosphorus was applied with a drill at a rate of 50 lbs/acre. This field was harvested on 8/5/81 and yielded 22.8 bushels of wheat per acre. Weight was 58 lbs/bushel with a protein content of 16.9%.

(b) Approximates the permanent wilting percentage for laboratory analysis.

(c) Negative values indicate a moisture deficit.

DISCUSSION AND RECOMMENDATIONS

Plant communities under study continue to respond both functionally and structurally to natural environmental fluctuations. Climatic variations, primarily the moisture balance, are thought to be the primary cause of the observed changes in plant communities. The collection of climatic and readily available soil moisture data is a step forward in accounting for this natural variation in prairie plant communities. Several years of data collection will be necessary before the relationship between climatic variables and vegetation can be assessed. The level of sampling accuracy attained in 1981 is thought to be adequate for this purpose.

Continued studies in 1982 should be based on the 1981 approach.

ACKNOWLEDGMENTS

Thanks go to the Mike McKeever family who made field work more pleasant than it might have been, and to Todd and Angie McKeever for collecting climate and soil moisture information. Taxonomic assistance from Dave Ramsden and Klaus Lackschewitz was much appreciated. Technical editing was performed by William Phippen, Carol Kopec, and Larry Thompson of DNRC. Graphs and mapping were done by June Virag of DNRC's Cartography Bureau.

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Appendix A. Plant species listed by family

Aceraceae

Acer negundo L.

Alismataceae

Alisma gramineum Gmel.

Amaranthaceae

Amaranthus graecizans L.
Amaranthus powellii Wats.

Anacardiaceae

Rhus aromatica Ait.(= *R. trilobata* Nutt.)
Rhus radicans L.

Apiaceae (= Umbelliferae)

Lomatium cous (Wats.) Coult. & Rose
Lomatium orientale Coult. & Rose
Musineon divaricatum (Pursh) Nutt.

Apocynaceae

Apocynum androsaemifolium L.
Apocynum cannabinum L.

Asclepiadaceae

Asclepias speciosa Torr.
Asclepias syriaca L.
Asclepias verticillata L.

Asteraceae (= Compositae)

Achillea millefolium L.
Agoseris glauca (Pursh) Raf.
Ambrosia artemisiifolia L.
Antennaria parvifolia Nutt.
Antennaria microphylla Rydb.
Arctium minus (Hill) Bernh.
Arctium lappa L.
Artemisia campestris L.
Artemisia cana Pursh
Artemisia dracunculus L.
Artemisia frigida Willd.
Artemisia longifolia Nutt.
Artemisia ludoviciana Nutt.
Artemisia tridentata Nutt.
Aster brachyactis Blake

Asteraceae (continued)

Aster falcatus Lindl.
Bidens vulgata Greene
Crepis occidentalis Nutt.
Chrysopsis villosa (Pursh) Nutt.
Chrysothamnus nauseosus (Pall.) Britt.
Chrysothamnus viscidiflorus (Hook.) Nutt.
Cirsium arvense (L.) Scop.
Cirsium flodmanii (Rydb.) Arthur
Cirsium undulatum (Nutt.) Spreng.
Cirsium vulgare (Savi) Tenore
Conyza canadensis (L.) Cronq.
Echinacea pallida Nutt.
Erigeron compositus Pursh
Erigeron engelmannii A. Nels.
Erigeron orchroleucus Nutt.
Erigeron pumilus Nutt.
Gnaphalium palustre Nutt.
Grindelia squarrosa (Pursh) Dunal
Gutierrezia sarothrae (Pursh) Britt. and Rusby (= *Xanthocephalum sarothrae*)
Haplopappus armerioides (Nutt.) Gray
Haplopappus spinulosus (Pursh) DC.
Helianthus annuus L.
Helianthus maximilianii Schrad.
Helianthus petiolaris Nutt.
Helianthus rigidus (Cass.) Desf.
Hymenopappus filifolius Hook
Hymenoxys acaulis (Pursh) Parker
Hymenoxys richardsonii (Hook.) Cockerell
Iva axillaris Pursh
Iva xanthifolia Nutt.
Lactuca ludoviciana (Nutt.) Riddell
Lactuca pulchella (Pursh.) DC.
Lactuca serriola L.
Liatris punctata Hook.
Lygodesmia juncea (Pursh.) D. Don
Machaeranthera canescens (Pursh) Gray
Machaeranthera grindelioides (Nutt.) Keck. and Cronq.
Machaeranthera tanacetifolia (H.B.K.) Nees
Microseris cuspidata (Pursh) Schultz-Bip.
Ratibida columnifera (Nutt.) Woot. & Standl.
Senecio canus Hook.
Senecio integerrimus Nutt.
Solidago missouriensis Nutt.
Solidago mollis Bartl.
Solidago nana Nutt.
Solidago rigida L.
Sonchus asper (L.) Hill
Sonchus uliginosus Bieb.
Taraxacum officinale Weber
Tetradymia canescens D.C.
Tragopogon dubius Scop.
Xanthium strumarium L.

Boraginaceae

Cryptantha celosioides (Eastw.) Pays.
Cryptantha interrupta (Greene) Pays.
Hackelia floribunda (Lehm.) Jtn.
Lappula echinata Gilib.
Lappula redowskii (Hornem) Greene
Lithospermum incisum Lehm.

Brassicaceae (= Cruciferae)

Alyssum alyssoides L.
Alyssum desertorum Stapf.
Arabis holboellii Hornem, var. *pendulocarpa* (Nels.) Rollins
Camelina microcarpa Andrz.
Capsella bursa-pastoris (L.) Medic.
Descurainia pinnata (Walt.) Britt.
Descurainia sophia (L.) Webb
Erysimum asperum (Nutt.) DC.
Erysimum cheiranthoides L.
Lepidium densiflorum Schrad.
Lepidium ruderale L.
Lesquerella alpina (Nutt.) Wats.
Lesquerella ludoviciana (Nutt.) Wats.
Rorippa calycina (Engelm.) Rydberg var. *calycina*
Rorippa sinuata (Nutt.) Hitchc.
Sisymbrium altissimum L.
Thlaspi arvense L.

Cactaceae

Coryphantha missouriensis (Sweet) Britt. & Rose
Coryphantha vivipara (Nutt.) Britt. & Brown
Opuntia fragilis (Nutt.) Haw.
Opuntia polyacantha Haw.

Campanulaceae

Campanula rotundifolia L.

Capparidaceae

Cleome serrulata Pursh.
Polanisia trachysperma T. & G.

Caprifoliaceae

Galium aparine L.
Symphoricarpos occidentalis Hook.

Caryophyllaceae

Cerastium arvense L.
Paronychia sessiliflora Nutt.

Chenopodiaceae

Atriplex argentea Nutt.
Atriplex canescens (Pursh) Nutt.
Atriplex confertifolia (Torr. & Frem.) Wats.
Atriplex dioica (Nutt.) Macbr.
Atriplex nuttallii Wats.
Bassia hyssopifolia (Pall.) Kuntze
Chenopodium album L.
Chenopodium glaucum L.
Chenopodium fremontii Wats.
Chenopodium leptophyllum (Moq.) Watts.
Chenopodium rubrum L.
Corispermum hyssopifolium L.
Eurotia lanata (Pursh) Moq. (= *Ceratoides lanata*)
Kochia scoparia (L.) Schrad.
Salicornia rubra A. Nels.
Salsola kali L.
Sarcobatus vermiculatus (Hook.) Torr.
Suaeda depressa (Pursh) Wats.
Suaeda intermedia Wats.

Commelinaceae

Tradescantia occidentalis (Britt.) Smyth.

Convolvulaceae

Convolvulus arvensis L.

Cornaceae

Cornus stolonifera Michx.

Cupressaceae

Juniperus communis L.
Juniperus horizontalis Moench
Juniperus scopulorum Sarg.

Cyperaceae

Carex brevior (Dewey) Mack.
Carex eleocharis Bailey
Carex filifolia Nutt.
Carex lanuginosa Michx.
Carex parryana Dewey
Carex praegracilis W. Boott
Carex sartwellii Dewey
Carex xerantica Bailey
Eleocharis acicularis (L.) R. & S.
Eleocharis macrostachya Britt. (= *E. palustris* (L.) R. & S.)
Scirpus acutus Muhl.
Scirpus americanus Pers.

Cyperaceae (continued)

Scirpus heterochaetus Chase
Scirpus maritimus L.

Elaeagnaceae

Sherphedia argentea (Pursh) Nutt.

Equisetaceae

Equisetum arvense L.
Equisetum fluviatile L.
Equisetum laevigatum A. Br.
Equisetum pratense Ehrb.

Euphorbiaceae

Euphorbia glyptosperma Engelm.
Euphorbia robusta (Engelm.) Small
Euphorbia serpyllifolia Pers.

Fabaceae (= Leguminosae)

Astragalus adsurgens Hook.
Astragalus agrestis Dougl.
Astragalus bisulcatus (Hook.) Gray
Astragalus canadensis L.
Astragalus crassicarpus Nutt.
Astragalus gilviflorus Sheld.
Astragalus kentrophyta Gray
Astragalus lotiflorus Hook.
Astragalus missouriensis Nutt.
Astragalus pectinatus Dougl.
Astragalus plattensis Nutt.
Astragalus purshii Dougl. (uncollected)
Astragalus spatulatus Sheld.
Glycyrrhiza lepidota (Nutt.) Pursh
Lupinus lepidus Dougl.
Lupinus pusillus Pursh
Medicago lupulina L.
Medicago sativa L.
Melilotus alba Desr.
Melilotus officinalis (L.) Lam.
Onobrychis viciaefolia Scop.
Oxytropis besseyi (Rydb.) Blank.
Oxytropis lambertii Pursh
Petalostemon candidum Michx.
Petalostemon purpureum (Vent.) Rydb.
Psoralea argophylla Pursh
Psoralea esculenta Pursh
Psoralea lanceolata Pursh
Thermopsis rhombifolia Nutt.
Trifolium repens L.
Vicia americana Muhl.

Haloragaceae

Myriophyllum spicatum L. var. *exalbescens* (Fernald) Jeps.
Myriophyllum hippuroides Nutt.

Hydrophyllaceae

Phacelia linearis (Pursh) Holz.

Iridaceae

Sisyrinchium angustifolium Miller

Juncaceae

Juncus balticus Willd.
Juncus bufonius L.
Juncus torreyi Cov.

Juncaginaceae

Triglochin maritimum L.

Lamiaceae (= Labiatae)

Hedeoma drummondii Benth.
Hedeoma hispida Pursh.
Lycopus americanus Muhl.
Mentha arvensis L.
Monarda fistulosa L.
Nepeta cataria L.
Salvia reflexa Hornem.

Liliaceae

Allium textile Nels. & Macbr.
Calochortus nuttallii T. & G.
Smilacina stellata (L.) Desf.
Streptopus amplexifolius (L.) DC.
Yucca glauca Nutt.
Zigadenus venenosus Wats.

Linaceae

Linum perenne L.
Linum rigidum Pursh

Loasaceae

Mentzelia decapetala (Pursh) Urb. & Gilg

Malvaceae

Malva parviflora L.
Sphaeralcea coccinea (Pursh) Rydb.

Najadaceae (= Potamogetonaceae)

Potamogeton pectinatus L.

Oleaceae

Fraxinus pennsylvanica Marsh.

Onagraceae

Gaura coccinea (Nutt.) Pursh
Oenothera caespitosa Nutt.
Oenothera serrulata Nutt.

Orobanchaceae

Orobanche fasciculata Nutt.
Orobanche ludoviciana Nutt.

Plantaginaceae

Plantago aristata Michx.
Plantago major L.
Plantago patagonica Jacq.

Poaceae(= Gramineae)

Agropyron caninum (L.) Beauv.
Agropyron cristatum (L.) Gaertn.
Agropyron dasystachyum (Hook.) Scribn.
Agropyron intermedium (Host) Beauv.
Agropyron smithii Rydb.
Agropyron spicatum (Pursh.) Scribn. & Smith
Agrostis scabra Willd.
Alopecurus pratensis L.
Andropogon scoparius Michx. (= Schizachrium scoparium)
Aristida longiseta Steud.
Avena fatua L.
Avena sativa L.
Beckmannia syzigachne (Steud.) Fernald
Bouteloua curtipendula (Michx.) Torr.
Bouteloua gracilis (H.B.K.) Lag. ex. Steud.
Bromus inermis Leys.
Bromus japonicus Thunb.
Bromus tectorum L.
Buchloe dactyloides (Nutt.) Engelm
Calamagrostis canadensis (Michx.) Beauv.
Calamagrostis montanensis Scribn.
Calamagrostis stricta (Timm) Koeler (= C. neglecta (Ehrh.) Gaertn.)
Calamovilfa longifolia (Hook.) Scribn.
Distichlis stricta (Torr.) Rydb.
Echinochloa crusgalli (L.) Beauv.
Elymus canadensis L.
Elymus glaucus Buckl.
Festuca octoflora Walt.

Poaceae (continued)

Hordeum jubatum L.
Hordeum vulgare L.
Koeleria pyramidata (Lam.) Beauv. (= *K. cristata* (L.) Pers.)
Muhlenbergia asperifolia (Nees & Meyen) Parodi
Muhlenbergia cuspidata (Torr.) Rydb.
Muhlenbergia racemosa (Michx.) B.S.P.
Munroa squarrosa (Nutt.) Torr.
Oryzopsis hymenoides (R. & S.) Ricker
Panicum capillare L.
Panicum virgatum L.
Phalaris arundinacea L.
Poa arida Vasey
Poa canbyi (Scribn.) Piper
Poa cusickii Vasey
Poa gracillima Vasey
Poa juncifolia Scribn.
Poa palustris L.
Poa pratensis L.
Poa sandbergii Vasey
Polypogon monspeliensis (L.) Desf.
Puccinellia nuttalliana (Schult.) Hitch. (= *P. airoides* (Nutt.) Wats & Coult.)
Schedonnardus paniculatus (Nutt.) Trel.
Sitanion hystrix (Nutt.) Smith
Spartina gracilis Trin.
Spartina pectinata Link.
Sporobolus airoides (Torr.) Torr.
Sporobolus cryptandrus (Torr.) Gray
Stipa comata Trin. & Rupr.
Stipa viridula Trin.
Triticum aestivum L.

Polemoniaceae

Collomia linearis Nutt.
Phlox alyssifolia Greene
Phlox hoodii Rich.
Phlox longifolia Nutt.

Polygalaceae

Polygala alba Nutt.

Polygonaceae

Eriogonum annuum Nutt.
Eriogonum cernuum Nutt.
Eriogonum flavum Nutt.
Eriogonum pauciflorum Pursh
Polygonum aviculare L.
Polygonum lapathofolium L.
Polygonum persicaria L.
Rumex maritimus L.
Rumex salicifolius Weinm.

Polypodiaceae

Cystopteris fragilis (L.) Bernh.

Portulacaceae

Portulaca oleracea L.

Ranunculaceae

Anemone nuttalliana DC.
Clematis ligusticifolia Nutt.
Delphinium bicolor Nutt.
Ranunculus cymbalaria Pursh
Thalictrum venulosum Trel.

Rosaceae

Amelanchier alnifolia Nutt.
Crataegus douglasii Lindl.
Geum triflorum Pursh
Geum macrophyllum Willd.
Potentilla anserina L.
Potentilla arguta Pursh
Potentilla norvegica L.
Potentilla paradoxa Nutt.
Potentilla pensylvanica L.
Prunus virginiana L.
Rosa acicularis Lindl.
Rosa arkansana Porter
Rosa nutkana Presl.
Rosa woodsii Lindl.

Rubiaceae

Galium aparine L.

Salicaceae

Populus deltoides Marsh.
Salix exigua Nutt.
Salix spp.

Santalaceae

Comandra umbellata (L.) Nutt.

Saxifragaceae (formerly Grossulariaceae)

Ribes americanum Mill.
Ribes aureum Pursh
Ribes cereum Dougl.
Ribes setosum Lindl.

Scrophulariaceae

Orthocarpus luteus Nutt.
Penstemon albidus Nutt.
Penstemon eriantherus Pursh
Penstemon gracilis Nutt.
Penstemon nitidus Dougl.

Selaginellaceae

Selaginella densa Rydb.

Solanaceae

Solanum rostratum Dunal
Solanum triflorum Nutt.

Typhaceae

Typha latifolia L.

Urticaceae

Parietaria pensylvanica Muhl.
Urtica dioica L.

Verbenaceae

Verbena bracteata Lag. & Rodr.

Violaceae

Viola nuttallii Pursh

Appendix B. Plant species by life form

Therophytes

Annuals

Alyssum alyssoides*
Alyssum desertorum
Amaranthus graecizans
Amaranthus powellii
Ambrosia artemisiifolia
Aster brachyactis
Atriplex argentea
Atriplex dioica*
Avena fatua
Avena sativa
Bassia hyssopifolia
Bidens vulgata
Bromus japonicus
Bromus tectorum
Camelina microcarpa
Capsella bursa-pastoris
Chenopodium album
Chenopodium glaucum
Chenopodium fremontii
Chenopodium leptophyllum
Chenopodium rubrum
Cleome serrulata
Collomia linearis
Conyza canadensis
Corispermum hyssopifolium
Descurainia pinnata
Descurainia sophia*
Echinochloa crusgalli
Eriogonum cernuum*
Erysimum cheiranthoides
Euphorbia serpyllifolia
Festuca octoflora
Galium aparine
Hedeoma hispida
Helianthus annuus
Helianthus petiolaris
Hordeum vulgare
Iva xanthifolia
Juncus bufonius
Kochia scoparia
Lappula echinata
Lappula redowskii
Lepidium densiflorum
Lepidium ruderale*
Linum rigidum
Lupinus pusillus
Machaeranthera tanacetifolia

* Denotes not found in intensive study area.

Therophytes (cont)

Annuals

Malva parviflora
Medicago lupulina
Munroa squarrosa
Orthocarpus luteus
Panicum capillare*
Parietaria pensylvanica
Plantago aristata
Plantago patagonica
Polanisia trachysperma
Polygonum aviculare*
Polygonum lapathifolium
Polypogon monspeliensis
Portulaca oleracea
Rumex maritimus*
Salicornia rubra
Salsola kali
Salvia reflexa*
Sisymbrium altissimum
Solanum rostratum
Sonchus asper
Solanum triflorum
Suaeda depressa
Thlaspi arvense
Triticum aestivum
Verbena bracteata
Xanthium strumarium

Biennials

Arctium lappa
Arctium minus
Cirsium vulgare
Eriogonum annuum*
Erysimum asperum
Lactuca serriola*
Machaeranthera canescens
Melilotus alba
Melilotus officinalis
Potentilla norvegica
Potentilla paradoxa
Tragopogon dubius

Geophytes

Agropyron dasystachyum
Agropyron smithii
Allium textile
Artemisia ludoviciana
Asclepias speciosa
Asclepias syriaca
Asclepias verticillata
Aster falcatus

Geophytes (cont)

Beckmannia syzigachne
Bouteloua curtipendula
Bromus inermis
Buchloe dactyloides
Calamagrostis canadensis
Calamagrostis montanensis
Calamagrostis stricta*
Calamovilfa longifolia
Calochortus nuttalli
Carex brevior
Carex eleocharis
Carex lanuginosa
Carex parryana
Carex praegracilis
Carex sartwellii
Carex xerantica
Cirsium arvense
Cirsium floodmanii
Cystopteris fragilis
Comandra umbellata*
Distichlis stricta
Eleocharis acicularis
Eleocharis palustris
Equisetum arvense
Equisetum fluviatile*
Equisetum laevigatum
Equisetum pratense
Euphorbia glyptosperma
Euphorbia robusta
Geum triflorum
Helianthus maximilianii
Helianthus rigidus
Iva axillaris
Juncus balticus
Juncus torreyi
Lactuca pulchella
Lomatium cous
Lomatium orientale
Lupinus lepidus
Lycopus americanus
Medicago sativa
Mentha arvensis
Muhlenbergia asperifolia
Muhlenbergia racemosa
Panicum virgatum
Phalaris arundinacea
Plantago major*
Poa arida
Poa palustris
Poa pratensis
Polygonum persicaria*
Potamogeton pectinatus

Geophytes (cont)

Potentilla anserina
Potentilla arguta*
Psoralea argophylla
Psoralea esculenta
Psoralea lanceolata
Ranunculus cymbalaria
Rorippa calycina
Rorippa sinuata
Scirpus acutus
Scirpus americanus
Scirpus heterochaetus
Scirpus maritimus
Sisyrinchium angustifolium
Smilacina stellata
Solidago missouriensis
Solidago mollis
Solidago nana
Solidago rigida
Spartina gracilis
Spartina pectinata
Sphaeralcea coccinea
Streptopus amplexifolius*
Thermopsis rhombifolia
Tradescantia occidentalis
Trifolium repens
Triglochin maritimum
Typha latifolia
Viola nuttallii
Zygadenus venenosus

Hemicryptophytes

Achillea millefolium
Agoseris glauca
Agrostis scabra
Agropyron caninum
Agropyron cristatum
Agropyron intermedium*
Agropyron spicatum
Alisma gramineum
Alopecurus pratensis
Andropogon scoparius
Anemone nuttalliana
Antennaria parvifolia
Antennaria microphylla
Arabis holboellii
Aristida longiseta
Astragalus adsurgens
Astragalus agrestis
Astragalus bisulcatus
Astragalus canadensis
Astragalus crassicarpus

Hemicryptophytes (cont)

Astragalus gilviflorus
Astragalus kentrophyta
Astragalus lotiflorus*
Astragalus missouriensis
Astragalus pectinatus
Astragalus plattensis
Astragalus purshii
Astragalus spatulatus
Bouteloua gracilis (or geophyte)
Campanula rotundifolia
Carex filifolia
Cerastium arvense*
Cirsium undulatum
Convolvulus arvensis
Coryphantha missouriensis*
Coryphantha vivipara
Crepis occidentalis
Cryptantha celosioides
Cryptantha interrupta
Delphinium bicolor
Echinacea pallida
Elymus canadensis
Elymus glaucus
Erigeron compositus
Erigeron engelmannii
Erigeron orchroleucus*
Erigeron pumilus
Eriogonum flavum
Eriogonum pauciflorum
Gaura coccinea
Geum macrophyllum
Glycyrrhiza lepidota
Gnaphalium palustre
Grindelia squarrosa
Hackelia floribunda
Haplopappus armerioides
Haplopappus spinulosus
Hedeoma drummondii
Hordeum jubatum
Hymenopappus filifolius
Hymenoxys acaulis
Hymenoxys richardsonii
Koeleria pyramidata
Lactuca ludoviciana
Lesquerella alpina
Lesquerella ludoviciana
Liatris punctata
Linum perenne
Lithospermum incisum
Lygodesmia juncea

Hemicryptophytes (cont)

Mentzelia decapetala
Microseris cuspidata
Monarda fistulosa
Muhlenbergia cuspidata
Musineon divaricatum
Myriophyllum hippuroides
Myriophyllum spicatum
Nepeta cataria
Oenothera caespitosa
Oenothera serrulata
Onobrychis viciaefolia
Orobanche fasciculata
Orobanche ludoviciana
Oryzopsis hymenoides
Oxytropis besseyi
Oxtyropis lambertii
Penstemon albidus
Penstemon gracilis
Penstemon nitidus
Petalostemon candidum
Petalostemon purpureum
Phacelia linearis
Poa canbyi
Poa cusickii*
Poa gracillima
Poa juncifolia
Poa sandbergii
Polygala alba
Potentilla pensylvanica
Puccinellia nuttalliana
Ratibida columnifera
Rumex salicifolius*
Schedonnardus paniculatus (or annual)
Senecio canus
Senecio integerrimus
Sitanion hystrix
Sonchus uliginosus
Sporobolus airoides
Sporobolus cryptandrus
Stipa comata
Stipa viridula
Taraxacum officinale
Thalictrum venulosum
Urtica dioica*
Vicia americana

Chamaephytes

Apocynum androsaemifolium
Apocynum cannabinum
Artemisia frigida
Artemisia campestris
Artemisia dracunculus

Chamaephytes (cont)

Artemisia longifolia
Atriplex nuttallii
Chrysopsis villosa
Eurotia lanata
Gutierrezia sarothrae
Juniperus horizontalis
Machaeranthera grindelioides
Opuntia fragilis
Opuntia polyacantha
Paronychia sessiliflora
Phlox alyssifolia
Phlox hoodii
Phlox longifolia*
Rhus radicans
Selaginella densa
Suaeda intermedia

Nanophanerophytes

Artemisia cana
Artemisia tridentata
Atriplex canescens
Atriplex confertifolia
Chrysothamnus nauseosus
Chrysothamnus viscidiflorus
Juniperus communis
Rhus aromatica
Ribes aureum
Ribes americanum
Ribes cereum
Ribes setosum
Rosa acicularis
Rosa arkansana
Rosa nutkana
Rosa woodsii
Sarcobatus vermiculatus
Symphoricarpos occidentalis
Tetradymia canescens
Yucca glauca

Microphanerophytes

Sprouters

Amelanchier alnifolia
Cornus stolonifera
Crataegus douglasii*
Prunus virginiana
Salix exigua
Salix spp.
Shepherdia argentea

Microphanerophytes (cont)

Non-sprouters

Juniperus scopulorum

Mesophanerophytes

Acer negundo
Fraxinus pennsylvanica
Populus deltoides

Lianas

Clematis ligusticifolia

MONTANA
DEPARTMENT OF NATURAL RESOURCES
& CONSERVATION

Helena, Montana

100 copies of this public document were published at an estimated cost of $2.78 per copy, for a total cost of $278.00, which includes $258.00 for printing and $20.00 for distribution.